Mobile Intel® GME 965 Chipset

Thermal Design Guide

August 2007

Order Number: 317567-001US

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Revision History

Date	Revision	Description
July 2007	001	Initial public release.

1.0 Introduction

To ensure quality, reliability, and performance goals are met over the product's life cycle, the heat generated by the device must be properly dissipated. Typical methods to improve heat dissipation include selective use of airflow ducting and/or the use of heat sinks. A properly designed thermal solution adequately cools the device die temperature at or below the thermal specification. This is accomplished by providing a suitable local-ambient temperature, ensuring adequate local airflow, and minimizing the die to local-ambient thermal resistance. Operation outside the functional limits can degrade system performance and may cause permanent changes in the operating characteristics of the component.

The goals of this document are to:

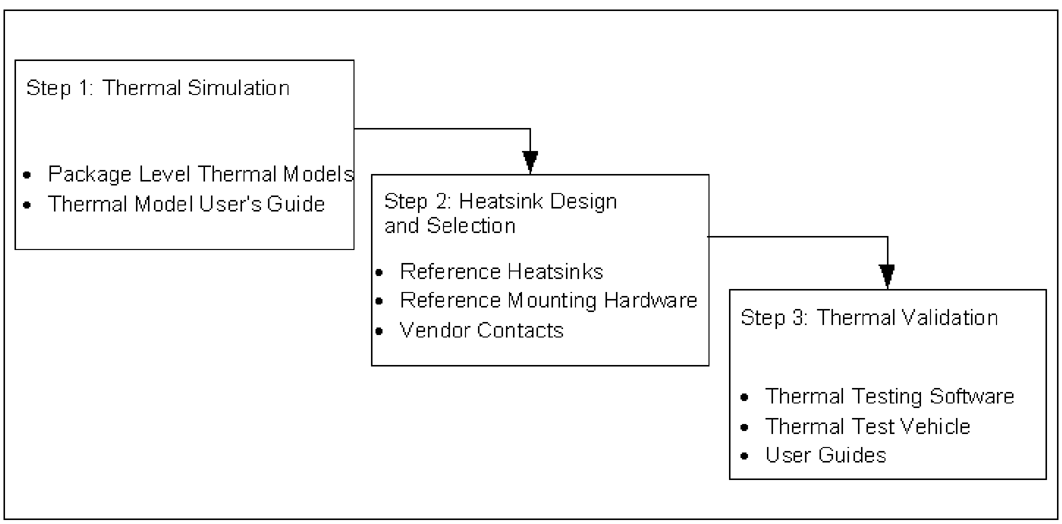
- Specify the thermal and mechanical specification for the Mobile Intel® GME 965 Chipset.
- Describe a reference thermal solution that meets the specifications.

This document addresses thermal and mechanical design specifications for Mobile Intel® GME 965 Chipset only. For thermal design information on other Intel® components, refer to the respective component datasheet.

1.1 Design Flow

Several tools are available from Intel to assist in the development of a reliable, cost-effective thermal solution. Figure 1 illustrates a typical thermal solution design process with available tools noted. The tools are available through your local Intel field sales representative.

Figure 1. Thermal Design Process



1.2 Definition of Terms

Table 1. Definition of Terms

Term	Definition
FCBGA	Flip Chip Ball Grid Array. A package type defined by a plastic substrate where a die is mounted using an underfill C4 (Controlled Collapse Chip Connection) attach style. The primary electrical interface is an array of solder balls attached to the substrate opposite the die. Note that the device arrives at the customer with solder balls attached.
Mobile Intel® GME 965 Chipset	Graphics and Memory Controller Hub
T_{CASE}	Maximum allowed component temperature. This temperature is measured at the geometric center of the top of the package die. Also referred to as T_C.
TDP	Thermal Design Power. Thermal solutions should be designed to dissipate this target power level.
TIM	Thermal Interface Material: thermally conductive material installed between two surfaces to improve heat transfer and reduce interface contact resistance.
T_{LA}	Local ambient temperature. This is the temperature measured inside the chassis, approximately 1" upstream of a component passive heat sink. Also referred to as T_A.
Ψ_{CA}	Case-to-ambient thermal characterization parameter. A measure of the thermal solution thermal performance including the TIM using total package power. Defined as $(T_{CASE} – T_{LA})$ / Total Package Power. Note: Heat source must be specified when using Ψ calculations.
Ψ_{CS}	Case-to-Sink thermal characterization parameter. A measure of the thermal interface material performance using total package power. Defined as $(T_{CASE} - T_{SINK})$/ Total Package Power. Note: Heat source must be specified when using Ψ calculations.
Ψ_{SA}	Sink-to-Ambient thermal characterization parameter. A measure of the heat sink performance using total package power. Defined as $(T_{SINK} - T_{LA})$/Total Package Power. Note: Heat source must be specified when using Ψ calculations.

1.3 Reference Documents

The reader of this specification should also be familiar with material and concepts presented in the following documents:

- Mobile Intel® GME 965 Chipset Datasheet
  — http://www.intel.com/design/mobile/datashts/316273.htm
- Mobile Intel® GME 965 Chipset: Enabling Support for PCI Express* Application Note
  — Contact field sales for application note:#665447
- Mobile Intel® 965 Express Chipset Family: Thermal Management Guide
  — Contact field sales for document: #646877

1.4 Thermal Model Availability

Intel provides thermal simulation models of the device and a thermal model user's guide to aid designers in simulating, analyzing, and optimizing thermal solutions in an integrated, system-level environment. The models are for use with commercially available Computational Fluid Dynamics (CFD)-based thermal analysis tools including Flotherm* (version 3.1 or higher) by Flomerics, Inc. or Icepak* by Fluent, Inc. Contact your Intel representative to order the thermal models and associated user's guides.

2.0 Thermal Specifications

2.1 Thermal Design Power

The thermal design power (TDP) specifications are listed in Table 2. Heat transfer through the FCBGA package and into the base board is limited. The cooling capacity without a thermal solution is also limited, so Intel recommends the use of a heat sink for all usage conditions

Table 2. Mobile Intel® GME 965 Chipset Thermal Design Power (TDP)

SKU	TDP	Unit	Notes
Mobile Intel® GME 965 Chipset • 500 MHz Render Clock	13.5	W	See Note
Mobile Intel® GME 965 Chipset • 500 MHz Render Clock • x2, x4 & x8 PCI Express*	14.3		
Mobile Intel® GME 965 Chipset • 400 MHz Render Clock	12.0		
Mobile Intel® GME 965 Chipset • 400 MHz Render Clock • x2, x4 & x8 PCI Express*	12.8		

Note: Thermal design power is the estimated maximum possible expected power generated in a component by a realistic application. It is based on extrapolations in both hardware and software technology over the life of the component. It does not represent the expected power generated by a power virus. Studies by Intel indicate that no application will cause thermally significant power dissipation exceeding this specification, although it is possible to concoct higher power synthetic workloads that write but never read. Under realistic read/write conditions, this higher power workload can only be transient and is accounted for in the Icc (max) specification.

2.2 Maximum Allowed Component Temperature

The Mobile Intel® GME 965 Chipset must maintain a maximum temperature at or below the value specified in Table 3 to ensure proper functionality and reliability. The thermal solution is required to meet the temperature specification when power dissipation is equal to TDP.

Table 3. Temperature Specifications

Symbol	Parameter	Min	Typ	Max	Unit	Notes
T_{die}	Die Temperature under bias	0		105° C	^{o}C	1
$T_{storage}$	Storage Temperature	-55		150		

Notes:

1. Die temperature (Tdie) is measured at the top surface of the die. See section 5 for temperature measurement metrology.

3.0 Mechanical Specifications

3.1 Package Keep-Out Zones Requirements

The heat sink must not touch the package in the areas shown in Figure 2. However, the heat sink should include a means to prevent the heat sink from forming an electrical short with the capacitors placed on the top side of the package. The reference thermal solutions includes a electrically insulated foam gasket that aids in preventing the heat sink from tilting and coming in contact with the die side capacitors. The package substrate should not be used as a load bearing structure for the thermal solution during shock and vibe events. However, it is ok to have a foam gasket come in contact with the substrate to prevent die tilt as mentioned above.

3.2 Board Level Keep-Out Zone Requirements

A general description of the keep-out zones and mounting hole pattern for the reference thermal solutions are shown in Appendix B, “Mechanical Drawings”.

3.3 Maximum Allowable Static Force

The Mobile Intel® GME 965 Chipset uses a FCBGA package with the back side of the die exposed. The backside of the die is the interface with the thermal solution. Since the die will come in contact with the thermal solution it is important to take precautions to avoid damaging the die or edges of the die. During thermal solution installation it is very important to avoid tilting the thermal solution and putting pressure on the edge of the die.

The thermal solution for the Mobile Intel® GME 965 Chipset shall not exceed a max static force of 15 lbf normal to the die. Any force larger than this could damage the device.

4.0 Thermal Solution Requirements

4.1 Thermal Characterization

The thermal characterization parameter, Ψ (the Greek letter psi), is used to characterize thermal performance in order to compare thermal solutions in identical situations (i.e., heating source, local ambient conditions, etc.). The thermal characterization parameter is calculated using total package power. The case-to-local ambient thermal characterization parameter (Ψ_{CA}) is used as a measure of the thermal performance of the overall thermal solution. It is defined by Equation 1 and measured in units of °C/W.

Equation 1. Case-to-Local Ambient Thermal Characterization Parameter (Ψ_{CA})

$$\Psi_{CA} = \frac{T_{CASE} - T_{LA}}{TDP}$$

The case-to-local ambient thermal characterization parameter, Ψ_{CA}, is comprised of Ψ_{CS}, the thermal interface material (TIM) thermal characterization parameter, and of Ψ_{SA}, the sink-to-local ambient thermal characterization parameter:

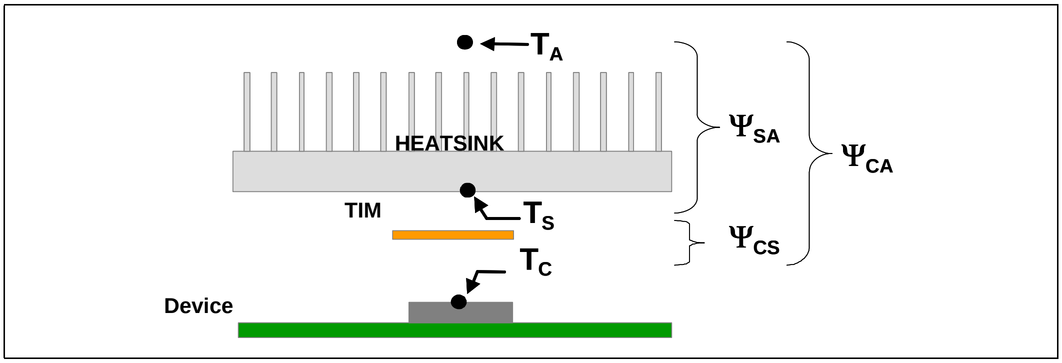
Equation 2. Case-to-Local Ambient Thermal Characterization Parameter (Ψ_{CA})

$$\Psi_{CA} = \Psi_{CS} - \Psi_{SA}$$

Ψ_{CS} is strongly dependent on the thermal conductivity and thickness of the TIM between the heat sink and die, as well as the uniformity of the clamping pressure between the sink and die.

Ψ_{SA} is the heatsink thermal characterization parameter from the heat sink reference point (temperature) to the local ambient air temperature. Ψ_{SA} is dependent on the heat sink material, thermal conductivity, and geometry. It is also strongly dependent on the air velocity through the fins of the heat sink. Figure 2 illustrates the combination of the different thermal characterization parameters.

Figure 2. Processor Thermal Characterization Parameter Relationships



Example 1. Calculating the Required Thermal Performance

The cooling performance, $\Psi_{CA,}$ is defined using the thermal characterization parameter previously described. The process to determine the required thermal performance to cool the device includes:

1. Define a target component temperature T_{CASE} and corresponding TDP.
2. Define a target local ambient temperature, T_{LA}.
3. Use Equation 1 and Equation 2 to determine the required thermal performance needed to cool the device.

The following provides an example of how to determine performance targets.

Assume:

- TDP = 14.3 W and T_{CASE} = 105° C
- Local processor ambient temperature, T_{LA} = 55° C.

Applying Equation 1 for the given chipset configuration to determine Ψ_{CA}:

$$\Psi_{CA} = \frac{T_{CASE} - T_{LA}}{TDP} = \frac{100 - 55}{14.3} = 3.15\ {}^{o}C/W$$

To determine the required heat sink performance, a heat sink solution provider would need to determine Ψ_{CS} performance for the selected TIM and mechanical load configuration. If the heat sink solution were designed to work with a TIM material performing at $\Psi_{CS} \leq 0.17$ °C/W, solving from Equation 2, the performance needed from the heat sink is:

$$\Psi_{CS} = \Psi_{CA} - \Psi_{SA} = 3.15 - 0.17 = 2.98\ {}^{o}C/W$$

The above example determines Ψ_{CS} for a relatively high ambient temperature, high TDP and relatively "good" TIM performance. Any change in these values for a specific application will redefine Ψ_{CS} for that application. Local operating environmental conditions, such as altitude, need to be understood since this will decrease air mass flow rate through the heatsink.

5.0 Reference Heat Sinks

Intel has developed reference heat sinks designed to meet the cooling needs of the Mobile Intel® GME 965 Chipset in embedded form factor applications. This chapter describes the overall requirements for the reference thermal solution including critical-to-function dimensions, operating environment, and verification criteria. This document details solutions that are compatible with the AdvancedTCA* and larger form factors. An additional design is shown for small form factors. The heat sink designs are not suitable for natural convection cooling and require a prescribed amount of system airflow. The system designer must ensure that suitable airflow is provided when using the reference heat sinks. A third party active heat sink (fan included) is available. Appendix A, "Thermal Solution Component Suppliers" contains vendor information for each component.

The heat sinks are attached to the board using a wire clip with each end hooked through an anchor soldered to the board. Figure 3 illustrates an example of the thermal solution assembly. Detailed mechanical drawings of the heat sinks and clip are provided in Appendix B, "Mechanical Drawings".

5.1 AdvancedTCA* Reference Heat Sink

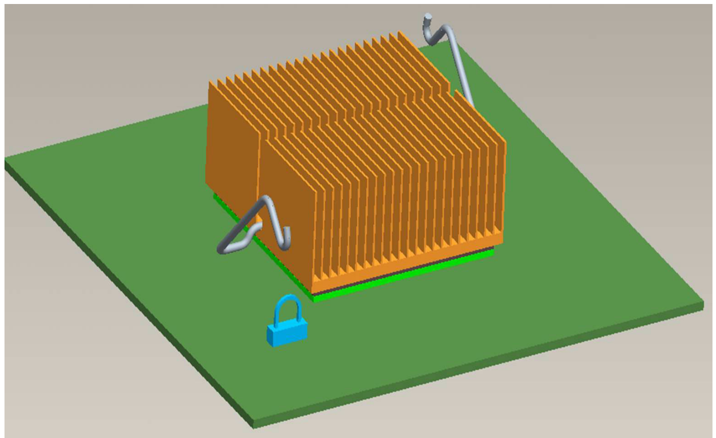
This reference heat sink is compatible with the AdvancedTCA* and larger (i.e., 1U) form factors. Figure 4 demonstrates the heat sink thermal performance at various airflow rates. Equation 1 and Equation 2 can be used to determine the acceptable ambient temperature range for this heat sink.

5.1.1 Mechanical Design

The reference heat sink is shown in Figure 3. The maximum heat sink height is constrained to 18.47 mm which enables use in most embedded form factors. The heat sink uses the torsional clip assembly (refer to Section 5.4) to mount to the PCB. Detailed drawings of this heat sink are provided in the Appendix B, "Mechanical Drawings".

The bottom surface of the heat sink includes a pedestal that interfaces with the top surface of the die. The pedestal is intended to provide clearance for capacitors placed on the top surface of the substrate. In addition, a foam gasket is attached to the heat sink's bottom surface to prevent the heat sink from tilting on the die. In rare occurrences, the heat sink could tilt and short with the capacitors if the gasket was not included. Other methods to prevent the heat sink base from shorting with the die side capacitor's can also be used, such as placing an electrically insulated material between the capacitors and heat sink base. The geometry of the pedestal and gasket are contained in the detailed drawings in Appendix B, "Mechanical Drawings".

Figure 3. AdvancedTCA* Reference Heat Sink Assembly



5.1.2 Keep-Out Zone Requirements

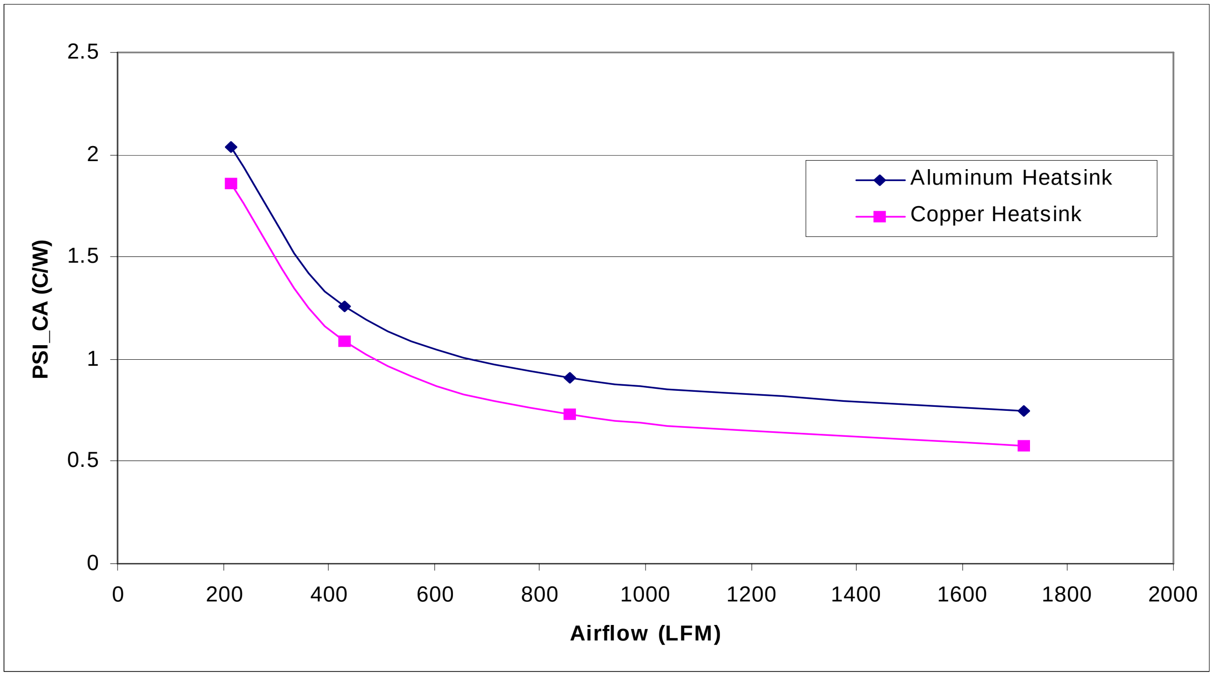
The required board keep-out zones are shown in Appendix B, “Mechanical Drawings”

5.1.3 Thermal Performance

The reference heat sink can be fabricated from either copper or aluminum. The copper version provides the best cooling, while the aluminum version cost less. Depending on the boundary conditions, both heat sinks can meet the thermal performance needed to cool the Mobile Intel® GME 965 Chipset in the AdvancedTCA* form factor. The heat sink performance versus airflow velocity is shown in Figure 4. The heat sink may be used in other form factors that can provide the required amount of airflow to meet the components thermal specifications.

The system integrator can make trade-offs to determine the best heat sink material to use based on usage conditions. For example, a higher ambient temperature might be considered with use of the copper heat sink [$T_{LA} = T_{CASE} - (\Psi_{CA}) \times (TDP)$].

Figure 4. AdvancedTCA* Reference Heat Sink Thermal Performance



5.2 Small Form Factor Reference Heat Sink

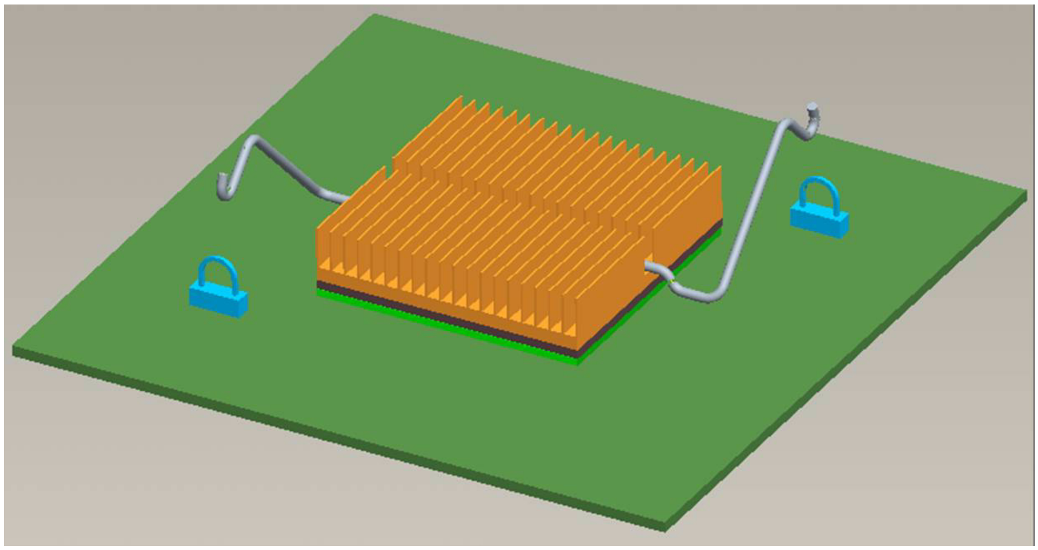
This reference heat sink is compatible with smaller embedded form factors (i.e., CompactPCI* and AdvancedMC*). Figure 6 demonstrates the heat sink thermal performance at various volumetric airflow rates. Equation 1 and Equation 2 can be used to determine the acceptable ambient temperature range that this heat sink can be used.

5.2.1 Mechanical Design

The small form factor reference thermal solution is shown in Figure 5. The heat sink fits within the volumetric keep-out zone outlined in Appendix B, "Mechanical Drawings". The maximum heat sink is constrained to 8.49 mm which enables use in commons small form factors such as Compact PCI* and the AdvancedMC* (mezzanine card). The heat sink uses the torsional clip assembly (refer to Section 5.4) to mount to the PCB. Detailed drawings of this heat sink are provided in Appendix B, "Mechanical Drawings".

The bottom surface of the heat sink includes a pedestal that interfaces with the top surface of the die. The pedestal is intended to provide clearance for capacitors placed on the top surface of the substrate. In addition, a foam gasket is included on the heat sink's bottom surface to prevent the heat sink from tilting. In rare occurrences, the heat sink could tilt and short the capacitors if the gasket is not included. Other methods to prevent the heat sink base from shorting with the die side capacitor's can also be used, such as placing an electrically insulated material between the capacitors and heat sink base. The geometry of the pedestal and foam gasket are contained in the detailed drawings in Appendix B, "Mechanical Drawings".

Figure 5. Small Form Factor Reference Heat Sink Assembly



5.2.2 Additional Keep-Out Zone Requirements

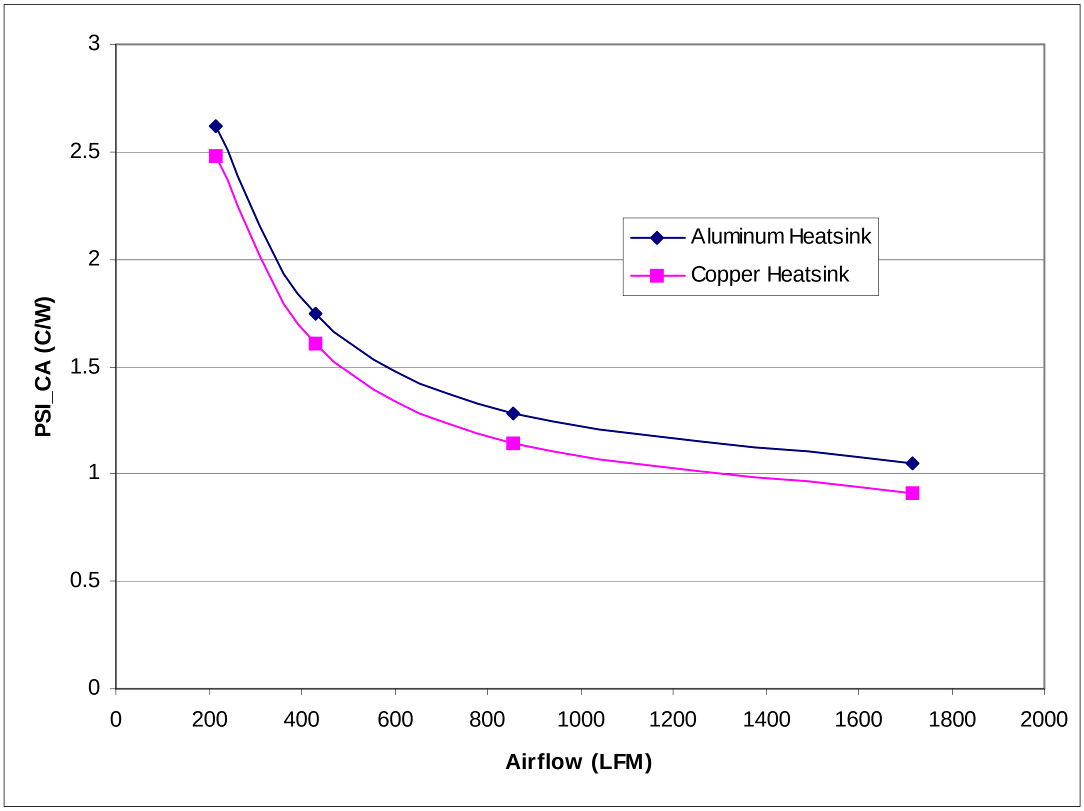
The volumetric constraints for this heat sink are shown in Appendix B, "Mechanical Drawings"

5.2.3 Thermal Performance

The small form factor reference heat sink can be fabricated from either copper or aluminum. The copper version provides the best cooling while the aluminum version cost less. Based on the boundary conditions, both versions can meet the thermal performance needed to cool the Mobile Intel® GME 965 Chipset.

The system integrator can make trade-offs to determine the best heat sink material to use based on usage conditions. For example, a higher ambient temperature might be considered with use of the copper heat sink [$T_{LA} = T_{CASE} – (\Psi_{CA})$ x (TDP)].

Figure 6. Small Form Factor Reference Heat Sink Thermal Performance



5.3 Active Heat Sink

An active heat sink that meets the thermal and mechanical requirements is available from third party vendors. The heat sink is suitable for benchtop use as well as other applications where system airflow is not available. The contact information for third party active heat sinks is available in Appendix A, "Thermal Solution Component Suppliers".

5.3.1 Mechanical Design

The active heat sink must fit within the volumetric keep-out zone outlined in Appendix B, "Mechanical Drawings". The heat sink should use the torsional clip assembly (refer to Section 5.4) to mount to the PCB.

5.3.2 Additional Keep-Out Zone Requirements

There are no other volumetric constraints required for the active heat sinks referenced in Appendix B, "Mechanical Drawings". However, if a different active heat sink is used, the board designers must ensure that any other keep-out requirements are addressed.

5.4 Torsional Clip

The reference solutions use wire clips with hooked ends. The hooks attach to wire anchors that fasten the clip to the board. The torsional clip is shown in Figure 3 and Figure 5. Refer to the detailed mechanical drawings in Appendix B, "Mechanical Drawings" for more information.

5.5 Solder-Down Anchors

The torsional clip uses a solder-down anchor to attach to the board. It is based on a standard three-pin jumper and is soldered to the board like any common through-hole header. The anchor design includes 45° bent leads to increase the anchor attach reliability over time. See Appendix A, “Thermal Solution Component Suppliers” for the part number and supplier information.

5.6 Heat Sink Orientation

Since the thermal solutions are based on unidirectional heat sinks, airflow direction must be aligned with the direction of the fins of the heat sink. Figure 3 and Figure 5 illustrate the orientation of the package, solder-down anchors, and heat sink relative to the system airflow.

5.7 Thermal Interface Material (TIM)

The thermal interface material provides improved conductivity between the die and heat sink. It is important to understand and consider the impact of the interface between the die and heat sink base to the overall thermal solution. Specifically, the bond line thickness, interface material area, and interface material thermal conductivity must be selected to optimize the thermal solution.

It is important to minimize the thickness of the thermal interface material, commonly referred to as the bond line thickness. A large gap between the heat sink base and the die yields a greater thermal resistance. The thickness of the gap is determined by the flatness of both the heat sink base and the die, plus the thickness of the thermal interface material, and the clamping force applied by the heat sink attachment method. To ensure proper and consistent thermal performance, the TIM and application process must be properly designed.

The Mobile Intel® GME 965 Chipset reference thermal solutions use Honeywell* PCM45F. Alternative materials can be used at your discretion. Regardless, the entire heat sink assembly, including the heat sink, and TIM (including attachment method), must be validated together for specific applications.

6.0 Thermal Metrology

The system designer must make measurements to accurately determine the performance of the thermal solution. The heat sink designs should be validated using a thermal test vehicle. The thermal test vehicle is a device that simulates the thermal characteristics of the Mobile Intel® GME 965 Chipset. It is also recommended to perform a final verification test of the heat sink with an actual Mobile Intel® GME 965 Chipset in a real working environment.

This section provides guidelines on techniques to perform thermal tests including:

- Section 6.1: Guidelines on how to accurately measure the component temperature.
- Section 6.2: Details the use of the thermal test vehicle.
- Section 6.2: Information on running a power simulation software that will emulate anticipated thermal design powers on an actual Mobile Intel® GME 965 Chipset.

6.1 Die Temperature Measurements

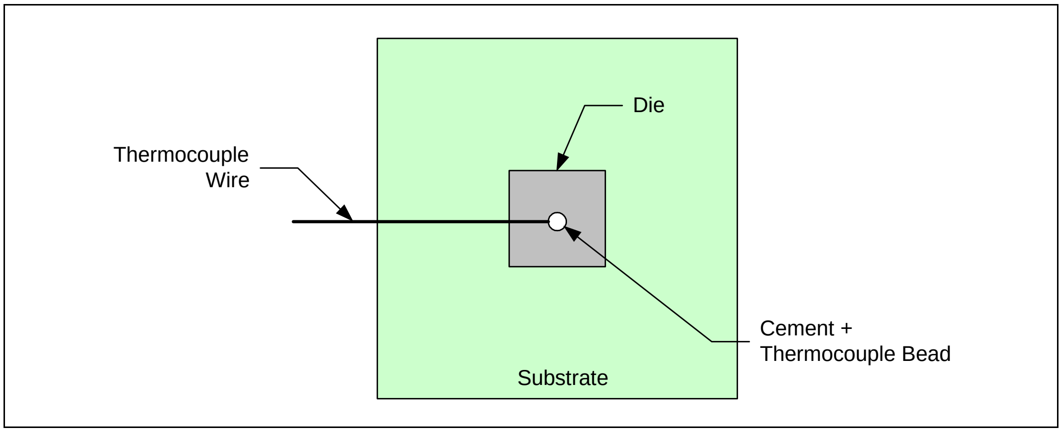
The component T_{CASE} must be maintained at or below the maximum temperature specification as noted in Table 3. The surface temperature at the geometric center of the die corresponds to T_{CASE}. Measuring T_{CASE} requires special care to ensure an accurate temperature measurement.

Temperature differences between the temperature of a surface and the surrounding local ambient air can introduce errors in the measurements. The measurement errors could be due to a poor thermal contact between the thermocouple junction and the surface of the package, heat loss by radiation and/or convection, conduction through thermocouple leads, or contact between the thermocouple attachment epoxy and the heat sink base. To maximize measurement accuracy, only the 0° attach approach described below should be used to attach the thermocouple.

6.1.1 0 Degrees Angle Thermocouple Attach Methodology

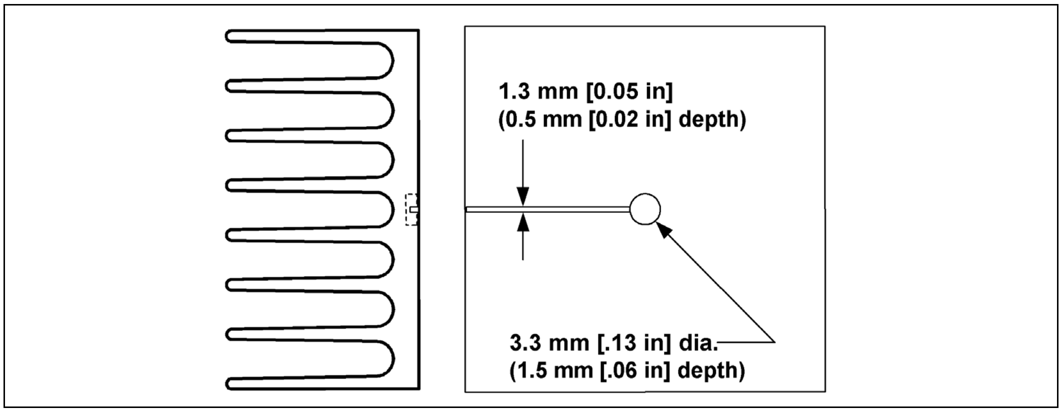
1. Mill a 3.3 mm (0.13 in.) diameter and 1.5 mm (0.06 in.) deep hole centered on the bottom of the heat sink base.
2. Mill a 1.3 mm (0.05 in.) wide and 0.5 mm (0.02 in.) deep slot from the centered hole to one edge of the heat sink (see Figure 7).
3. Attach thermal interface material to the bottom of the heat sink base.
4. Cut out portions of the TIM to make room for the thermocouple wire and bead. The cutouts should match the slot and hole milled into the heat sink base.
5. Attach a 36 gauge or smaller calibrated K-type thermocouple bead or junction to the center of the top surface of the die using a high thermal conductivity cement. During this step, ensure no contact is present between the thermocouple cement and the heat sink base because it may affect the thermocouple reading. **It is critical that the thermocouple bead makes contact with the die** (see Figure 7).
6. Attach the heat sink assembly to the Mobile Intel® GME 965 Chipset and route thermocouple wires out through the milled slot.

Figure 7. 0 Degrees Angle Attach Methodology (Top View)



Note: Not to scale.

Figure 8. 0 Degrees Angle Attach Heat Sink Modifications



Note: Not to scale.

6.2 Power Simulation Software

The power simulation software is a utility designed to dissipate the thermal design power on the Mobile Intel® GME 965 Chipset. To assess the thermal performance of the Mobile Intel® GME 965 Chipset thermal solution under “worst-case realistic application” conditions, Intel has developed a software utility that operates the product at near worst-case realistic power dissipation. Contact your Intel Field representative to obtain the maximum power program for the Mobile Intel® GME 965 Chipset.

7.0 Reliability Guidelines

Each motherboard, heat sink, and attach combination may vary the mechanical loading of the component. The user should carefully evaluate the reliability of the completed assembly prior to use in high volume. Some general recommendations are shown in Table 4.

Table 4. Reliability Requirements

Test[1]	Requirement	Pass/Fail Criteria[2]
Mechanical Shock	50 g, board level, 11 msec, 3 shocks/axis	Visual Check and Electrical Functional Test
Random Vibration	7.3 g, board level, 45 min/axis, 50 Hz to 2000 Hz	Visual Check and Electrical Functional Test
Temperature Life	85° C, 2000 hours total, checkpoints at 168, 500, 1000, and 2000 hours	Visual Check
Thermal Cycling	-5° C to +70° C, 500 cycles	Visual Check
Humidity	85% relative humidity, 55° C, 1000 hours	Visual Check

Notes:
1. The above tests should be performed on a sample size of at least 12 assemblies from three lots of material.
2. Additional Pass/Fail Criteria may be added at the discretion of the user.

Appendix A Thermal Solution Component Suppliers

A.1 Reference Heat Sink

Table 5. Reference Heat Sink

Part	Intel Part Number	Supplier (Part Number)	Contact Information
AdvancedTCA* Heat Sink Assembly	N/A	ECB-00307-02-GP (Copper) ECB-00306-02-GP (Aluminum)	Wendy Lin 510-770-8566, x211 Wendy@coolermaster.com
Small Form Factor Heat Sink Assembly	N/A	ECB-00304-02-GP (Aluminum) ECB-00305-02-GP (Copper)	Wendy Lin 510-770-8566, x211 Wendy@coolermaster.com
Active Heat Sink	N/A	ECB-00208-03	Wendy Lin 510-770-8566, x211 Wendy@coolermaster.com
Thermal Interface PCM45F	N/A	Honeywell* (PCM45F)	Paula Knoll 858-705-1274 paula.knoll@honeywell.com
Heat Sink Attach Clip	A69230-001	CCI/ACK*	Harry Lin (USA) 714-739-5797 hlinack@aol.com Monica Chih (Taiwan) 866-2-29952666, x131 monica_chih@ccic.com.tw
		Foxconn*	Bob Hall (USA) 503-693-3509, x235 bhall@foxconn.com
Solder-Down Anchor	A13494-005	Foxconn (HB96030-DW)	Julia Jiang (USA) 408-919-6178 juliaj@foxconn.com

Note: The enabled components may not be currently available from all suppliers. Contact the supplier directly to verify time of component availability.

Appendix B Mechanical Drawings

This section lists the following mechanical drawings:

- Figure 9, "ATCA Reference Heatsink Assembly" on page 24
- Figure 10, "Small Form Factor Reference Heatsink" on page 25
- Figure 11, "Keepout Zones for ATCA & Small Form Factor Heatsinks and Retention" on page 26

Figure 9. ATCA Reference Heatsink Assembly

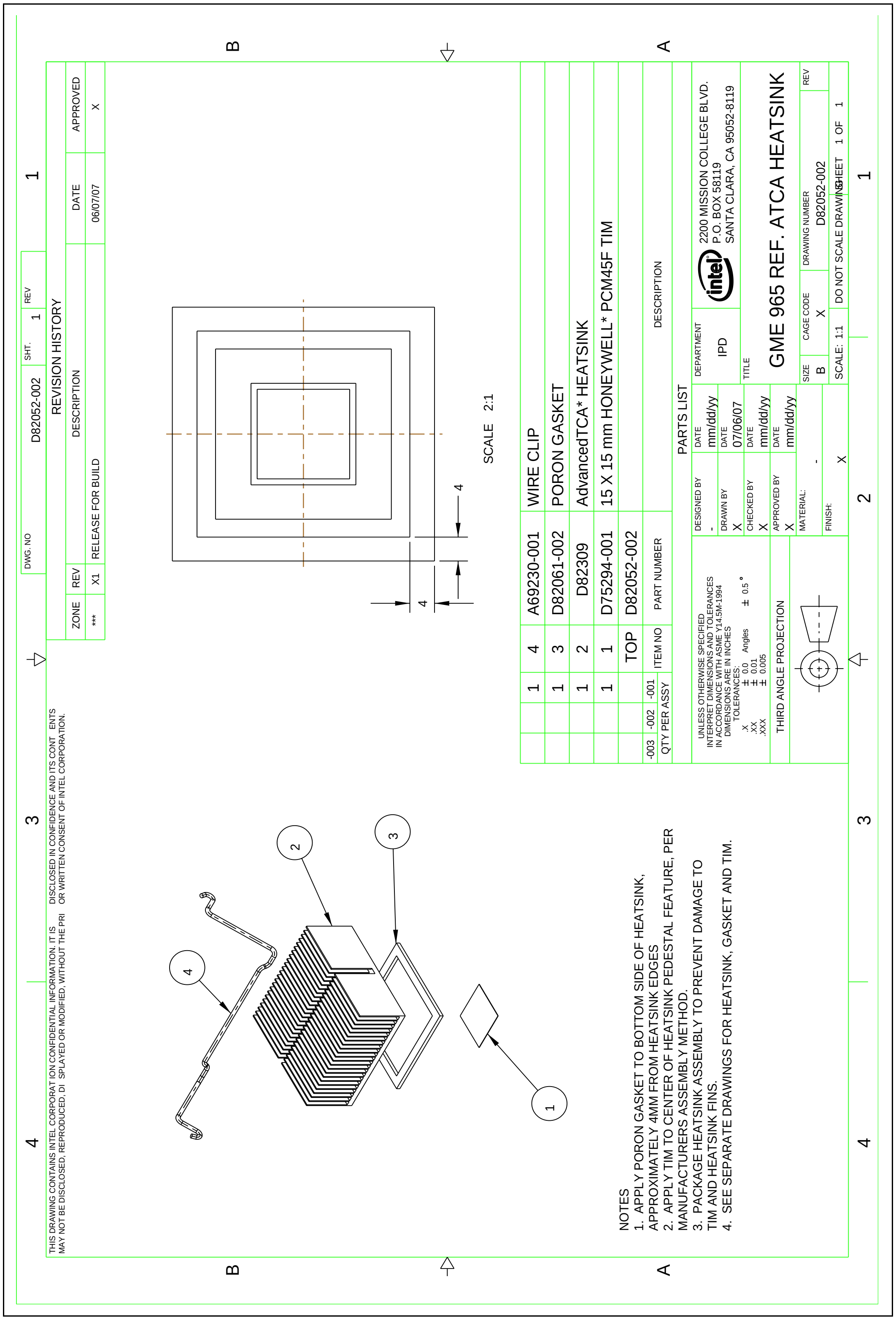


Figure 10. Small Form Factor Reference Heatsink

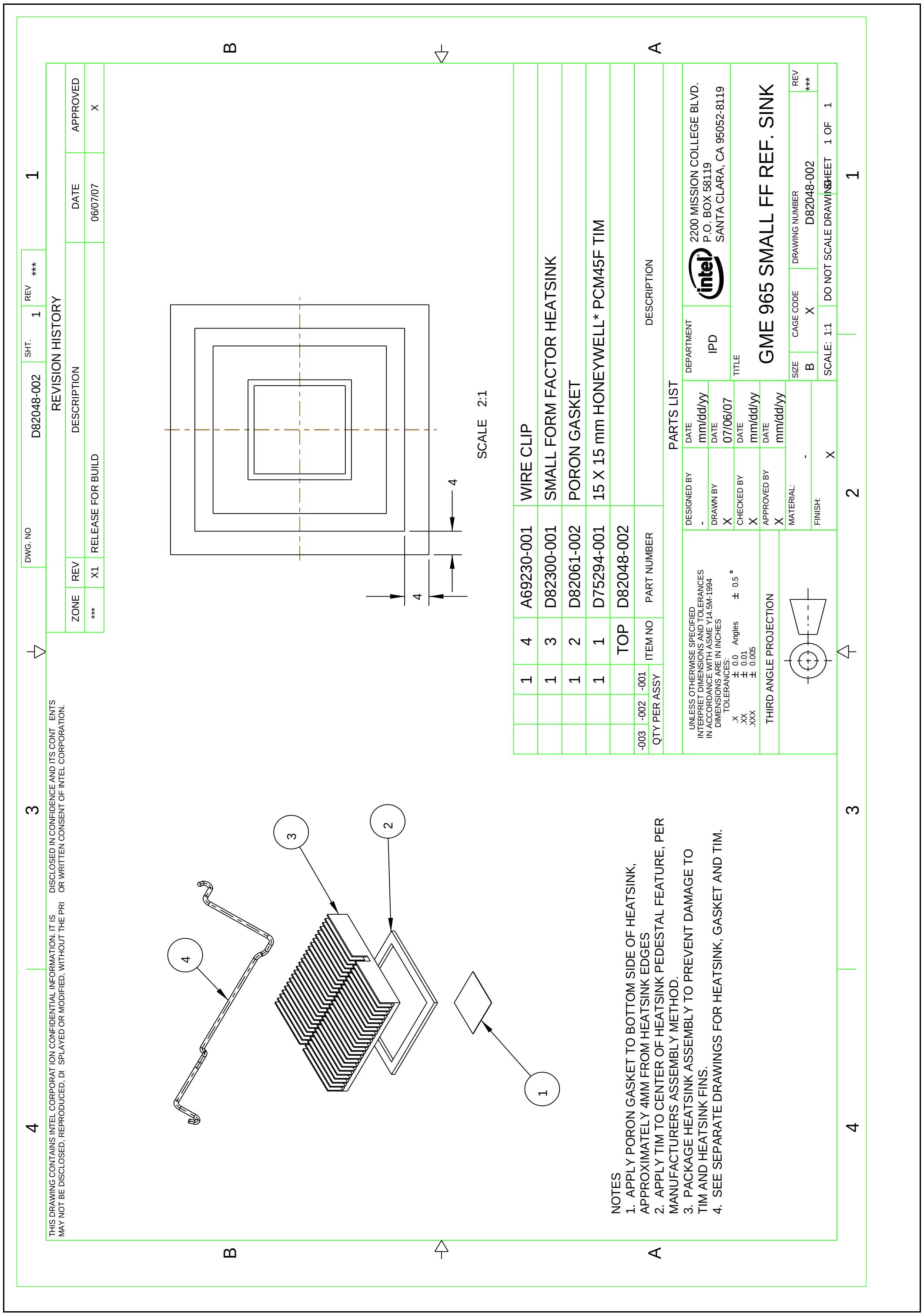


Figure 11. Keepout Zones for ATCA & Small Form Factor Heatsinks and Retention